JC20 Rec'd PCT/PTO SEP 2 6 2001

FORM PTO-1390 (Modified) (REV 10-95)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
1782

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
09/937608

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE 00/00915	**MARCH 26, 2000**	**MARCH 30, 1999**

TITLE OF INVENTION
METHOD FOR SYNCHRONIZATION

APPLICANT(S) FOR DO/EO/US
Markus RADIMIRSCH, Karsten BRUENINGHAUS, Urs LUEBBERT

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 18 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
    A **SECOND** or **SUBSEQUENT** preliminary amendment.
16. ☐ A substitute specification.
17. ☐ A change of power of attorney and/or address letter.
18. ☒ Certificate of Mailing by Express Mail
19. ☐ Other items or information:

ET473367352 US

PCTUS1/REV03

JC09 Rec'd PCT/PTO 26 SEP 2001

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/937608	PCT/DE 00/00915	1782

20. The following fees are submitted:.

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		
☐ Search Report has been prepared by the EPO or JPO **$930.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) **$720.00**		
☐ No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) **$790.00**		
☒ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO **$1,070.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) **$98.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$1,000.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	18 - 20 =	0	x $18.00	**$0.00**	
Independent claims	3 - 3 =	0	x $80.00	**$0.00**	
Multiple Dependent Claims **(check if applicable)**.			☒	**$270.00**	
	TOTAL OF ABOVE CALCULATIONS =			**$1,270.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)**. ☐				**$0.00**	
	SUBTOTAL =			**$1,270.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
	TOTAL NATIONAL FEE =			**$1,270.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable)**. ☐				**$0.00**	
	TOTAL FEES ENCLOSED =			**$1,270.00**	
				Amount to be: refunded	$
				charged	$

☐ A check in the amount of to cover the above fees is enclosed.

☒ Please charge my Deposit Account No. **19-4675** in the amount of **$1,270.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **19-4675** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

STRIKER, STRIKER & STENBY
103 EAST NECK ROAD
HUNTINGTON, NEW YORK 11743

SIGNATURE

MICHAEL J. STRIKER
NAME

27233
REGISTRATION NUMBER

SEPTEMBER 26, 2001
DATE

09937608.030102

JC18 R

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09/959-106
9/937-608

UNITED STATES PATENT AND TRADEMARK OFFICE

In re:

Applicant: RADIMIRSCH, M., et al

Serial No.: 09/937,608

Filed: 09/26/2001

For: METHOD FOR SYNCHRONIZATION

PRELIMINARY AMENDMENT

December 17, 2001

Hon. Commissioner of
Patents and Trademarks
Washington, D.C. 20231

Sir:

Preliminarily to the issuance of an Office Action in the above identified application, please amend the same as follows:

Box: PCT

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231.
On 12/17/01

In the specification

Please amend the specification as attached:

In the claims:

Cancel all claims without prejudice.

Add the following claims as attached:

REMARKS

This Amendment is submitted preliminary to the issuance of an Office Action in the above identified application.

With the present Amendment applicant has amended the specification to bring it in compliance with the requirements of the U.S. Patent Practice.

The original claims have been canceled and replaced with a new set of claims including claims 17, the broadest method claim as well as claims related to the new transmitter, receiver, communication system and broadcasting communication system.

The claims have been drafted also in accordance with the requirements of the U.S. Patent Practice and to more clearly define the present invention.

Consideration and allowance of present application is most respectfully requested.

Should the Examiner require or consider it advisable that the specification, claims and/or drawings be further amended or corrected in formal respects in order to place this case in condition for final allowance, then it is respectfully requested that such amendments or corrections be carried out by Examiner's Amendment, and the case be passed to issue. Any costs involved should be charged to the deposit account of the undersigned (No. 19-4675). Alternatively, should the Examiner feel that a personal discussion might be helpful in advancing this case to allowance, he is invited to telephone the undersigned (at 631-549-4700).

Respectfully submitted,

Michael J. Striker
Attorney for Applicants
Reg. No. 27233

In the specification:

Page 1, line 1, change the heading "Prior Art" to -- BACKGROUND OF THE INVENTION --.

Page 3, line 1, change the heading "Advantages of the Invention" to -- SUMMARY OF THE INVENTION --.

Amend paragraph 1 on page 3 as follows:

With the provisions according to [claim 1] <u>the invention</u>, the precision of synchronization can be improved considerably over known methods. While the known methods can actually be used only for coarse block synchronization, the method according to the invention offers quite precise results both in terms of fine block estimation and frequency estimation. The embodiment according to the invention is advantageously suitable as a transmission method for OFDM. If a coherent demodulation is provided, then the synchronization train can be used for block synchronization, and estimating the center frequency error can also be used to estimate the channel pulse response.

Page 4, line 7, change the heading “DRAWINGS” to -- BRIEF DESCRIPTION OF THE DRAWINGS --.

Page 4, line 22, change the heading “DESCRIPTION OF THE EXEMPLARY EMBODIMENTS” to -- DESCRIPTION OF THE PREFERRED EMBODIMENTS --.

Amended paragraph 1 on page 3:

With the provisions according to the invention, the precision of synchronization can be improved considerably over known methods. While the known methods can actually be used only for coarse block synchronization, the method according to the invention offers quite precise results both in terms of fine block estimation and frequency estimation. The embodiment according to the invention is advantageously suitable as a transmission method for OFDM. If a coherent demodulation is provided, then the synchronization train can be used for block synchronization, and estimating the center frequency error can also be used to estimate the channel pulse response.

CLAIMS

17. A method of synchronizing at least one or more receivers to a transmitter within a transmission system with the use of a data stream with guard intervals, comprising the steps of inserting with the transmitter a special synchronization train into the data stream at a beginning of a transmission, which train is capable of estimating a chronological position of a signal to be received and/or estimating a center frequency error between the transmitter and the receiver; forming the synchronization train of at least two different symbol sequences which are transmitted in alternation periodically; ascertaining the chronological position of the signal and/or the center frequency error between the transmitter and the receiver from a composite term of various symbol sequences within a predetermined interval; for a block synchronization using total metrics of at least two different symbol sequences used as the synchronization train; and selecting as a beginning of a block, whichever index minimizes the total metrics within the predetermined interval.

18. A method as defined in claim 17; and further comprising providing in an OFDM transmission symbol the symbol sequences

comprising OFDM symbols, which have same lengths as or different lengths from a conventional data symbol.

19. A method as defined in claim 17; and further comprising transmitting the symbol sequences at least in pairs in each case in alternation.

20. A method as defined in claim 17, wherein when there are more than two different symbol sequences, further comprising putting at least one symbol sequence as a pair together with a spacing from at least one further pair of another symbol sequence to form the synchronization train.

21. A method as defined in claim 20; and further comprising providing guard intervals in front of the individual pairs of symbol sequences.

22. A method as defined in claim 17; and further comprising, for a block synchronization, using total metrics of at least two different symbol frequencies used as the synchronization train, and as a beginning of a block selecting whichever index minimizes the total metrics within the predetermined interval.

23. A method as defined in claim 17; and further comprising determining the predetermined interval by a frame structure of the data stream.

24. A method as defined in claim 17; and further comprising for estimating the center frequency error, ascertaining a phase rotation of two adjacent identical signal segments at a time.

25. A method as defined in claim 24; and further comprising ascertaining phase rotations of other identical signal portions, and estimating a total center frequency error by averaging via the phase rotations thus obtained.

26. A method as defined in claim 17; and further comprising utilizing the symbol sequences for channel estimation for a coherent demodulation, in that the symbol sequence after a frequency correction has been performed is subjected in the receiver to a fast Fourier transformation, and determining amplitudes and phase weights of individual subcarriers.

27. A method as defined in claim 26; and further comprising estimating channel parameters by averaging various symbol sequences.

28. A method as defined in claim 17; and further comprising preceding the synchronization train by a preamble which is used to adjust an amplitude control of the receiver.

29. A transmitter for preparing a synchronization train for at least one receiver within a transmission system with use of a data stream with guard intervals for compensating for multi-path propagation, the transmitter comprising a first device selected from the group consisting of a coding device and a modulating device; and insertion device for a synchronization train, which is formed of at least two different symbol sequences, said insertion device being embodied such that an alternating, periodic insertion of the synchronization train into the data stream prepared by said fist device can be performed; and a memory device operatively connected to said insertion device for various symbol sequences and for their linkage.

30. A receiver for receiving and evaluating a synchronization train which can be transmitted by a transmitter within a transmission system with use of a data stream with guard intervals to compensate for multi-path propagation, the receiver comprising a sampling memory for a received data stream; a synchronization evaluation device which is operatively connected

to said sampling memory and is suitable for evaluating a synchronization train including at least two different symbol sequences that can be transmitted periodically in alternation with respect to a chronological position and/or a center frequency error within a predetermined interval, and for controlling corresponding reception units for block synchronization, frequency synchronization and/or channel estimation.

31. A communication system using the method of claim 17 and embodied as a radio communication system, a line-connected communication system, or a hybrid communication system with radio components, optical waveguide components and/or line-connected components, said communication system including one transmitter and one receiver assigned to subscribers, with variable transmission and reception modes.

32. A communication system using the transmitter of claim 29 or the receiver of claim 30 and embodied as a radio communication system, a line-connected communication system, or a hybrid communication system with radio components, optical waveguide components and/or line-connected components, said communication system including one transmitter and one

receiver assigned to subscribers, with variable transmission and reception modes.

33. A broadcasting communication system using the method of claim 17 and embodied as a radio communication system, a line-connected communication system, or a hybrid communication system with radio components, optical waveguide components and/or line-connected components, said broadcast communication system being formed so that an association of a transmission and a reception mode is finally specified.

34. A broadcasting communication system using the transmitter of claim 29 or the receiver of claim 30 and embodied as a radio communication system, a line-connected communication system, or a hybrid communication system with radio components, optical waveguide components and/or line-connected components, said broadcast communication system being formed so that an association of a transmission and a reception mode is finally specified.

09/937608

JC09 Rec'd PCT/PTO 26 SEP 2001

UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner: Group: Attorney Docket # 1782

Applicant(s) : RADIMIRSCH, M., ET AL

Serial No. :

Filed :

For : METHOD FOR SYNCHRONIZATION

SIMULTANEOUS AMENDMENT

September 26, 2001

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

S I R S:

Simultaneously with filing of the above identified application please amend the same as follows:

In the Claims:

Cancel all claims without prejudice.

Substitute the claims attached hereto.

REMARKS:

This Amendment is submitted simultaneously with filing of the above identified application.

With the present Amendment applicant has amended the claims so as to eliminate their multiple dependency.

Consideration and allowance of the present application is most respectfully requested.

Respectfully submitted,

Michael J. Striker
Attorney for Applicant(s)
Reg. No. 27233

Claims

1. A method for synchronizing one or more receivers to a transmitter within a transmission system, using a data stream with guard intervals, in particular for compensating for multi-path propagation, having the following provisions:

- the transmitter (S) inserts a special synchronization train into the data stream, especially at the beginning of the transmission, which train is capable of estimating the chronological position of the signal to be received and/or estimating the center frequency error between the transmitter (S) and the receiver (E);

- the synchronization train is formed of at least two different symbol sequences (A, B), which are transmitted in alternation periodically;

- the chronological position of the signal to be received, and/or the center frequency error between the transmitter (S) and the receiver (E), is ascertained from a composite term of the various symbol sequences (A, B) within a predetermined interval.

2. The method of claim 1, characterized in that in an OFDM transmission system, the symbol sequences (A, B) comprise OFDM symbols, which have the same lengths as or different lengths from a conventional data symbol.

3. The method of claim 1 [or 2], characterized in that the symbol sequences (A, B) are transmitted at last in pairs in each case in alternation.

4. The method of claim 1 [or 2], characterized in that when there are more than two different symbol sequences, at least one symbol sequence as a pair is put together with a spacing from at least one further pair of another symbol sequence to form the synchronization train.

5. The method of claim 3 [or 4], characterized in that guard intervals in front of the individual pairs of symbol sequences (AA, BB, AA, ...) are provided.

6. The method of [one of claims 1-5] claim 1, characterized in that for a block synchronization, the total metrics of the at least two different symbol sequences used as the synchronization train are used, and as the beginning of a block, whichever index minimizes the total metrics within the predetermined interval is selected.

7. The method of [one of claims 1-6] claim 1, characterized in that the predetermined interval is determined by the frame structure of the data stream.

8. The method of [one of claims 1-7] claim 1, characterized in that for estimating the center frequency error, the phase rotation of two adjacent identical signal segments at a time is ascertained.

9. The method of claim 8, characterized in that the phase rotations of other identical signal portions are also ascertained, and the total center frequency error is estimated by averaging via the phase rotations thus obtained.

10. The method of [one of claims 1-9] claim 1,

characterized in that the symbol sequences are utilized for channel estimation for a coherent demodulation, in that the symbol sequence after a frequency correction has been performed is subjected in the receiver to an FFT transformation (Fast Fourier Transformation), and the amplitudes and phase weights of the individual subcarriers are determined.

11. The method of claim 10, characterized in that the channel parameters are estimated by averaging via the various symbol sequences (A, B).

12. The method of [one of claims 1-11] <u>claim 1</u>, characterized in that the synchronization train is preceded by a preamble (P), which is used in particular to adjust the amplitude control (GC) of the receiver (E).

13. A transmitter (S) for preparing a synchronization train for at least one receiver (E) within a transmission system, using a data stream with guard intervals, in particular for compensating for multi-path propagation, having the following characteristics:

- a coding or modulating device (CM),

- an insertion device (EB) for a synchronization train, which is formed of at least two different symbol sequences (A, B), the insertion device (EB) being embodied such that an alternating, periodic insertion of the synchronization train into the data stream prepared by the coding and modulating device (CM) can be performed;

- a memory device (SP), operatively connected to the

insertion device (EB), for the various symbol sequences and for their linkage.

14. A receiver (E) for receiving and evaluating a synchronization train which can be transmitted by a transmitter (S) within a transmission system, using a data stream with guard intervals, in particular to compensate for multi-path propagation, having the following characteristics:

- a sampling memory (AS) for a received data stream;

- a synchronization evaluation device (SY), which is operatively connected to the sampling memory (AS) and is suitable for evaluating a synchronization train, comprising at least two different symbol sequences (A, B) that can be transmitted periodically in alternation, with respect to the chronological position and/or center frequency error within a predetermined interval, and for controlling corresponding reception units for block synchronization (BS), frequency synchronization (FS), and/or channel estimation (KS).

15. A communications system using the method of [one of claim 1-12] <u>claim 1</u> or an arrangement of claim 13 [or 14], which is embodied as a radio communications system, a line-connected communications system, or a hybrid communications system, that is, as a communications system with radio components, optical waveguide components and/or line-connected components, and in which one transmitter and one receiver are assigned to subscribers, with variable transmission and reception modes.

16. A broadcasting communications system using the method of [one of claim 1-12] <u>claim 1</u> or an arrangement of claim 13 [or

14], which is embodied as a radio communications system, a line-connected communications system, or a hybrid communications system, that is, as a communications system with radio components, optical waveguide components and/or line-connected components, and in which the association of the transmission and reception mode is fixedly specified.

Claims

1. A method for synchronizing one or more receivers to a transmitter within a transmission system, using a data stream with guard intervals, in particular for compensating for multi-path propagation, having the following provisions:

- the transmitter (S) inserts a special synchronization train into the data stream, especially at the beginning of the transmission, which train is capable of estimating the chronological position of the signal to be received and/or estimating the center frequency error between the transmitter (S) and the receiver (E);

- the synchronization train is formed of at least two different symbol sequences (A, B), which are transmitted in alternation periodically;

- the chronological position of the signal to be received, and/or the center frequency error between the transmitter (S) and the receiver (E), is ascertained from a composite term of the various symbol sequences (A, B) within a predetermined interval.

2. The method of claim 1, characterized in that in an OFDM transmission system, the symbol sequences (A, B) comprise OFDM symbols, which have the same lengths as or different lengths from a conventional data symbol.

3. The method of claim 1, characterized in that the symbol sequences (A, B) are transmitted at last in pairs in each case in alternation.

4. The method of claim 1, characterized in that when there are more than two different symbol sequences, at least one symbol sequence as a pair is put together with a spacing from at least one further pair of another symbol sequence to form the synchronization train.

5. The method of claim 3, characterized in that guard intervals in front of the individual pairs of symbol sequences (AA, BB, AA, ...) are provided.

6. The method of claim 1, characterized in that for a block synchronization, the total metrics of the at least two different symbol sequences used as the synchronization train are used, and as the beginning of a block, whichever index minimizes the total metrics within the predetermined interval is selected.

7. The method of claim 1, characterized in that the predetermined interval is determined by the frame structure of the data stream.

8. The method of claim 1, characterized in that for estimating the center frequency error, the phase rotation of two adjacent identical signal segments at a time is ascertained.

9. The method of claim 8, characterized in that the phase rotations of other identical signal portions are also ascertained, and the total center frequency error is estimated by averaging via the phase rotations thus obtained.

10. The method of claim 1, characterized in that the symbol sequences are utilized for channel estimation for a coherent demodulation, in that the symbol sequence after a

frequency correction has been performed is subjected in the receiver to an FFT transformation (Fast Fourier Transformation), and the amplitudes and phase weights of the individual subcarriers are determined.

11. The method of claim 10, characterized in that the channel parameters are estimated by averaging via the various symbol sequences (A, B).

12. The method of claim 1, characterized in that the synchronization train is preceded by a preamble (P), which is used in particular to adjust the amplitude control (GC) of the receiver (E).

13. A transmitter (S) for preparing a synchronization train for at least one receiver (E) within a transmission system, using a data stream with guard intervals, in particular for compensating for multi-path propagation, having the following characteristics:

- a coding or modulating device (CM),

- an insertion device (EB) for a synchronization train, which is formed of at least two different symbol sequences (A, B), the insertion device (EB) being embodied such that an alternating, periodic insertion of the synchronization train into the data stream prepared by the coding and modulating device (CM) can be performed;

- a memory device (SP), operatively connected to the insertion device (EB), for the various symbol sequences and for their linkage.

14. A receiver (E) for receiving and evaluating a synchronization train which can be transmitted by a transmitter (S) within a transmission system, using a data stream with guard intervals, in particular to compensate for multi-path propagation, having the following characteristics:

- a sampling memory (AS) for a received data stream;

- a synchronization evaluation device (SY), which is operatively connected to the sampling memory (AS) and is suitable for evaluating a synchronization train, comprising at least two different symbol sequences (A, B) that can be transmitted periodically in alternation, with respect to the chronological position and/or center frequency error within a predetermined interval, and for controlling corresponding reception units for block synchronization (BS), frequency synchronization (FS), and/or channel estimation (KS).

15. A communications system using the method of claim 1 or an arrangement of claim 13, which is embodied as a radio communications system, a line-connected communications system, or a hybrid communications system, that is, as a communications system with radio components, optical waveguide components and/or line-connected components, and in which one transmitter and one receiver are assigned to subscribers, with variable transmission and reception modes.

16. A broadcasting communications system using the method of claim 1 or an arrangement of claim 13, which is embodied as a radio communications system, a line-connected communications system, or a hybrid communications system, that is, as a communications system with radio components, optical waveguide

components and/or line-connected components, and in which the association of the transmission and reception mode is fixedly specified.

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METHOD FOR SYNCHRONIZATION

Prior Art

The invention is based on a method for synchronizing one or more receivers to a transmitter within a transmission system, using a data stream with guard intervals, in particular for compensating for multi-path propagation, and on a transmitter for preparing a synchronization train and a receiver for evaluating this synchronization train, and on a communications system.

It is assumed for instance that one transmitter serves one or more receivers. The transmitter sends one or more packets to the receivers at the same instant.

In a transmission system, which in particular uses OFDM (Orthogonal Frequency Division Multiplexing), the problem of synchronization arises. In OFDM transmission, the transmission symbols are modulated over a plurality of subcarriers in the frequency range by a generally digital type of modulation [1]. The subcarriers are then transformed into the time range together by an IFFT (Inverse Fast Fourier Transformation) and then transmitted.

In the receiver, it is necessary to reconstruct some information by way of the signal transmitted, especially to reconstruct the beginning of the block and the center frequency error.

To ascertain the beginning of the block, the chronological position of the signal to be received must be known. For this purpose, a two-stage method is usually used,

according to which first a coarse and then a fine detection of the beginning of the block are performed in succession.

In the normal situation, the receiver has a center frequency error compared to the sensor. In the case of OFDM, this error is especially critical, because it can cause a disruption of orthogonality, which leads to increased bit errors. The frequency synchronization serves to correct this frequency difference.

In a communications system with transmission of relatively short data packets, to achieve a synchronization, two identical synchronization symbols, especially OFDM symbols, are made to precede a transmission burst in accordance with [2], [3] and [4], and these are transmitted twice with a predetermined spacing. The position of these signals can be determined by evaluation of the metrics.

To avoid intersymbol interferences (ISI), a guard interval is often inserted into the transmitter in conjunction with the OFDM transmission technique, the length of which guard interval is adapted to the duration of the channel pulse response. In order for there not to be any actual disruption in the receiver from chronologically adjacent symbols, the instant of synchronization, that is, the onset of the ISI-free signal portion, is ascertained before the data evaluation in the receiver. The ascertainment of this instant is called block or symbol synchronization. When the pulse response of the present channel is shorter than the guard interval, the block synchronization need not ascertain the beginning of the ON state precisely; instead, the result is an allowable synchronization interval.

Advantages of the Invention

With the provisions according to claim 1, the precision of synchronization can be improved considerably over known methods. While the known methods can actually be used only for coarse block synchronization, the method according to the invention offers quite precise results both in terms of fine block estimation and frequency estimation. The embodiment according to the invention is advantageously suitable as a transmission method for OFDM. If a coherent demodulation is provided, then the synchronization train can be used for block synchronization, and estimating the center frequency error can also be used to estimate the channel pulse response.

The effort and expense for implementing the method of the invention is hardly higher than in known methods but provides increased accuracy of the estimate, especially of the center frequency error.

The method according to the invention, and a corresponding transmitter and receiver, are advantageously suitable for use in radio systems, specifically in normal bidirectional communications systems with variable distribution of the roles of transmitter and receiver and in broadcasting systems, in which the roles of transmitter and receiver are static over time.

As a transmission medium, not only radio but also a line connected transmission can be provided, for instance via coaxial cable or a shielded or unshielded pair of conductors in a line network. In hybrid communications systems as well, that is, systems with radio components, line-connected components, and/or light source conductor components, the

invention can advantageously be used.

OFDM is especially suitable as the type of modulation. But even in systems without OFDM, where transmission methods are used in which a guard interval is provided to compensate for multi-path propagation, the invention can advantageously be employed.

Drawings

In conjunction with the drawings, exemplary embodiments will be explained in further detail. Shown are:

Fig. 1, a radio network with one transmitter and a plurality of receivers;

Fig. 2, the makeup of a synchronization train according to the prior art;

Fig. 3, the makeup of a synchronization train according to the invention;

Fig. 4, the makeup of a synchronization train with a preamble;

Fig. 5, a block circuit diagram of a transmitter according to the invention;

Fig. 6, a block circuit diagram of a receiver according to the invention.

Description of Exemplary Embodiments

Before the actual embodiment according to the invention

will be addressed, for the sake of better comprehension synchronization according to the prior art will be explained. For the following observations, it will be assumed that in Fig. 1 a transmitter S of a subscriber serves a plurality of receivers E1, E2, E3 of other subscribers.

The transmitter S of a subscriber sends one or more data packets to the receivers E1, E2, E3 at one instant; the duration of the packets can be either constant or variable. The situation can generally also change in such a way that one of the subscribers later switches over dynamically from the reception mode to the transmission mode, and a transmitting subscriber and/or the other receiving subscribers then operate in the reception mode.

It is also assumed that OFDM is used as the transmission method; see [1], [3], [4]. To that end, the transmission symbols over a plurality of subcarriers are modulated in the frequency range by a generally digital type of modulation. The subcarriers are then transformed into the time range together by an IFFT (Inverse Fast Fourier Transformation) and then transmitted.

Since in a communications system only short data packets are transmitted, fast synchronization is urgently needed. This can be achieved only with the aid of a special synchronization symbol, which is made to precede the data packet in the transmitter.

One known method of block synchronization, found in sources [2] and [3], is to evaluate a signal $A = \{r_i\}$ of length N, which is transmitted twice at the spacing P; see Fig. 2. The position of this signal can be determined by evaluation of the metrics:

$$\begin{aligned}
\lambda(i,N,P) &= \min_{\varphi}\left\{\sum_{j=0}^{N-1}\left|r(i+j)-r(i+j+P)e^{j\varphi}\right|^2\right\}\\
&= \min_{\varphi}\left\{\sum_{j=0}^{N-1}\left|r(i+j)\right|^2+\left|r(i+j+P)\right|^2-2\mathrm{Re}\left\{r(i+j)r^*(i+j+P)e^{-j\varphi}\right\}\right\}\\
&= \sum_{j=0}^{N-1}\left[\left|r(i+j)\right|^2+\left|r(i+j+P)\right|^2\right]-2\left|\sum_{j=0}^{N-1}r(i+j)r^*(i+j+P)\right|\\
&= E(i,N,P)-2\left|w(i,N,P)\right|
\end{aligned}$$

The criterion for the beginning of the block is indicated by the index i, at which the metrics have their minimal phase:

$$i_{start} = \arg\min_{i} \lambda(i,N,P)$$

The block synchronization in the OFDM system should, on the basis of the periodic preamble, indicate the interference-free range of the subsequent data blocks. To that end, the correlation window is shortened relative to the sequence length by the length of the guard interval.

This method described above is actually used for coarse block synchronization. In principle, it therefore offers only quite imprecise results, in terms of both fine block estimation and frequency estimation.

The transmitter S of Fig. 1 inserts a special synchronization train, especially at the beginning of transmission, into the data stream; in the receiver, this sequence serves to estimate the chronological position of the signal to be received, and/or to estimate the center frequency error between the transmitter and the receiver. The synchronization train is formed according to the invention as follows:

- two different symbol sequences A and B of the same

length L_1 with ideally favorable autocorrelation properties are selected. In the case of OFDM, these can be OFDM symbols, which have the same length as or a different length from a normal data symbol;

- the two symbol sequences A and B are always transmitted in such a way that in alternation, A is transmitted twice and B is transmitted twice, as in Fig. 3. The indexes for the symbol sequences A and B indicate the occurrence of the trains A and B.

The chronological position of the signal to be received between the transmitter S and receiver E is ascertained from a composite term, in particular the total metrics, of the various symbol sequences, in this case the pairs of symbol sequences, within a predetermined interval.

Then in the receiver the total metrics λ_S, from the sum of individual metrics λ over all the identical sequence pairs (A_I, A_m) and (B_I, B_m), where $1 \leq 1$, $m \leq M$ and $m >$, become the following:

$$\lambda_S(i) = \sum_{(A_l, A_m) \in M_A} \lambda(i + S(A_l, A_m), L_1, \Delta(A_l, A_m)) + \sum_{(B_l, B_m) \in M_B} \lambda(i + S(B_l, B_m), L_1, \Delta(B_l, B_m))$$

In this equation, S (X,Y) designates the relative starting index for the signal interval X, and Δ (X,Y) designates the spacing between the two pairs of signals X,Y.

Whichever index i_{Start} that minimizes the metrics λ_S within an interval I_{RS} predetermined by the frame synchronization is selected as the beginning of the block:

$$i_{start} = \arg\min_{i \in I_{RS}} \lambda_S(i)$$

In the frequency estimation, the problem arises that the phase rotation between two identical symbols (A_1, A_m) and (B_1, B_m) can exceed 360°, so that the resultant multivalence must first be solved. As the reference frequency fref for this, the estimated frequency position f_o from the phase rotation $\hat{\phi}_{01}$

of two adjacent periodic segments each must be used, since here the capture range, where $|f_o\| < f_a / (\pi L_1)$ is greatest:

$$f_{ref} = \hat{f}_{o1} = \frac{f_a \cdot \hat{\varphi}_{o1}}{2\pi L_1}$$

where

$$\hat{\varphi}_{o1} = \arg\left\{ \sum_{l=1,3,5,\ldots}^{M-1} w(i_{start} + S(A_l, A_{l+1}), L_1, L_1) + w(i_{start} + S(B_l, B_{l+1}), L_1, L_1) \right\}.$$

To achieve the most secure possible frequency estimation, once again the phase rotations for all the other pairs of intervals (A_1, A_m) and (B_1, B_m) must be taken into account. Let $M_{A\delta} \subset M_A$ and $M_{b\delta} \subset M_B$ be the set of all the pairs (A_1, A_m) and (B_1, B_m) with the same spacing $\Delta(A_1, A_m)$ and $\Delta(B_1, B_m)$, and let δ_{max} be the number of different sets $M_{A/B\delta 1/}$, then the overall result for the estimated value of the center frequency error f_0 is:

$$\hat{f}_o = \sum_{\delta=1}^{\delta_{max}} c_\delta \cdot \hat{f}_{o\delta} = \sum_{\delta=1}^{\delta_{max}} c_\delta \frac{f_a \hat{\varphi}_{o\delta} \cdot e^{-jW(\hat{\varphi}_{o1}, \hat{\varphi}_{o\delta})}}{2\pi\delta(A_l, A_m \in M_{A\delta})}$$

where

$$\hat{\varphi}_{o\delta} = \arg\left\{ \sum_{(A_l, A_m) \in M_{A,\delta}} w(i_{start} + S(A_l, A_m), L_1, \Delta(A_l, A_m)) + \sum_{(B_l, B_m) \in M_{B,\delta}} w(i_{start} + S(B_l, B_m), L_1, \Delta(B_l, B_m)) \right.$$

The coefficients c_δ are weighting factors, with which the different noise levels, which are superimposed on the estimated phase values, are taken into account. They result on the one hand from the number of sequence pairs that are taken into account and on the other from the spacing (X,Y) of the frequency pairs. The function [paste in, page 9, line 4] solves the multivalence of the phase [ditto, line 5] on the basis of the estimated phase value [ditto, line 6] ascertained beforehand.

According to the invention, the symbols indicated can also be used for channel estimation, if they are known in the transmitter and the receiver. To that end, the synchronization symbols, once the frequency correction has been done, are FFT-processed in the receiver, and the amplitude weights and phase weights of the individual subcarriers are determined. If the synchronizing signals (A and B) are shorter than a normal OFDM symbol, then the phase weights and amplitude weights of the subcarriers not transmitted must be ascertained by interpolation. The fact that a plurality of known synchronizing symbols are used can be exploited for the sake of averaging the channel parameters over the known symbols, so as to increase the accuracy of the channel estimation.

It should now be assumed that the transmitter places a preamble in accordance with Fig. 4 before each synchronization train. The synchronization train according to the invention is preceded by a preamble that serves to set the gain control of the receiver correctly, in order to fully modulate the analog-to-digital converter. The ensuing

synchronization symbol comprises the sequence AABBAA.

The metrics for the block synchronization in this case are calculated as follows:

$$\lambda_S(i) = \lambda(i, L_1, L_1) + \lambda(i, L_1, 4L_1) + \lambda(i, L_1, 5L_1) + \lambda(i + L_1, L_1, 3L_1) \\ + \lambda(i + L_1, L_1, 4L_1) + \lambda(i + 4L_1, L_1, L_1) + \lambda(i + 2L_1, L_1, L_1)$$

The individual metrics correspond to the pairs (A_1, A_2), (A_1, A_3), (A_1, A_4), (A_2, A_3), (A_2, A_4), (A_3, A_4), (B_1, B_2). The starting value for the block is:

$$i_{start} = \arg\min_i \lambda_S(i)$$

For the frequency synchronization, the center frequency error f_0 is calculated as follows:

$$\hat{\varphi}_{01} = \arg\{w(i_{start}, L_1, L_1) + w(i_{start} + 2L_1, L_1, L_1) + w(i_{start} + 4L_1, L_1, L_1)\},$$

$$\hat{\varphi}_{02} = \arg\{w(i_{start}, L_1, 4L_1) + w(i_{start} + L_1, L_1, 4L_1)\}$$

$$\hat{f}_0 = \frac{f_c}{2\pi}\left(c_1 \frac{\hat{\varphi}_{01}}{L_1} + c_2 \frac{\hat{\varphi}_{02} e^{-jF(\hat{\varphi}_{01}, \hat{\varphi}_{02})}}{4L_1}\right)$$

One possible realization of the transmitter is shown in Fig. 5. An OFDM transmitter, that is, its coding and modulating device CM, is supplied with a bit train. The usual processing by IFFT (Inverse Fast Fourier Transformation), parallel-serial conversion P/S, and the insertion of the guard interval SI follows by periodic continuation (see source [1]). Next, at the beginning of each transmission, the synchronization train is read out of a memory SP and inserted, together with the preamble of Fig. 4,

by means of the insertion device EB. The signal is converted from digital to analog (D/A) and transferred to the transmission front end SF, where it is optionally highly mixed into a different frequency position and is transmitted via an antenna. In the version of Fig. 5, the insertion of the synchronization train is done in accordance with the IFFT, so that in the memory SP, the time signal of the synchronization train must be present. Under certain conditions, however, it is equally possible to insert the synchronization train before the IFFT and have it processed by the IFFT.

One possible version of the receiver is shown in Fig. 6. In the receiver, the signal, mixed into the base band and converted from analog to digital, reaches a sampling memory AS. The synchronizing device SY can access this sampling memory AS in order to perform the block synchronization, frequency synchronization, and channel estimation. Once the block synchronization has been successfully performed, a window-forming unit BS is addressed, which reads the correct values out of the sampling buffer memory. Next, a frequency correction is performed in the mixing device FS with the center frequency error ascertained. After the serial-parallel conversion S/P and the FFT processing, the channel parameters ascertained from the channel estimation are used for demodulation and decoding DM.

Next, alternatives for realizing the method of the invention will be presented:

- in the method for calculating the total metrics, it is also possible not to take all the possible pairs into account. In the exemplary embodiment, the calculation prescription for the block synchronization would for instance

change as follows:

$$\lambda_3(i) = \lambda(i, L_1, L_1) + \lambda(i, L_1, 4L_1) + \lambda(i + L_1, L_1, 4L_1) + \lambda(i + 4L_1, L_1, L_1) + \lambda(i + 2L_1, L_1, L_1)$$

The individual metrics would in this case correspond to the pairs (A_1, A_2), (A_1, A_3), (A_2, A_4), (A_3, A_4), (B_1, B_2).

It is equally possible in the method for calculating the center frequency error to use only some of the possible angle errors in calculating the equation for $\phi_{0\delta}$.

- Under some circumstances, it is favorable to insert guard intervals before the individual frequency pairs. If S is a guard interval of arbitrary length (in general, the periodic continuation of a symbol), the result is thus for example the train SAASBBSAA. The calculation prescriptions described above logically apply, and the guard intervals are not evaluated.

- By the method described above, the signal trains A and B are each transmitted in pairs a plurality of times in succession. The method for block and frequency synchronization can be analogously used if the signal trains occur individually one after the other, such as the train ABAB. It is equally possible for the trains A and B not be inserted in pairs but each more than twice. One example of a train for a triple occurrence each time would be AAABBBAAA. The calculation prescriptions given above logically apply.

It is furthermore possible to use more than two different signal trains, such as three different signal trains A, B and C. The rule in this case would be that at least one signal train is put together as a pair, with a

spacing of more than one further pair of other signal trains, to make a synchronizing symbol.

It is also possible to transmit the various signal trains not directly in succession but rather with a certain spacing from one another.

The method presented is based on the fact that the various signal trains each have the same length. It is also possible to use different signal trains A and B that have different lengths. The calculation prescriptions logically apply and must be adapted in detail for this purpose.

Literature:

[1] W. Zou, Y. Wu, "COFDM: an Overview", IEEE Transactions on Broadcasting, Vol. 41, No. 1, March 1995

[2] Chevillat, P.R., Mainwald, D., Ungerboeck, G. (1987), Rapid Training of a Voiceband Data-Modem Receiver Employing an Equalizer with Fractional-T Spaced Coefficients, IEEE Transactions on Communications 35(9), 869-876

[3] Müller-Weinfurtner, S.H. (1998), On the Optimality of Metrics for Coarse Frame Synchronization in OFDM: a Comparison, 9th IEEE PIMRC '98

[4] Müller-Weinfurtner, S.H., Rößler, J.F., Huber, J.B. (1998), Analysis of a Frame- and Frequency Synchronizer for Bursty OFDM, Proceedings of the 7th CTMC at IEEE Globecom '98, pp.201-206

Claims

1. A method for synchronizing one or more receivers to a transmitter within a transmission system, using a data stream with guard intervals, in particular for compensating for multi-path propagation, having the following provisions:

- the transmitter (S) inserts a special synchronization train into the data stream, especially at the beginning of the transmission, which train is capable of estimating the chronological position of the signal to be received and/or estimating the center frequency error between the transmitter (S) and the receiver (E);

- the synchronization train is formed of at least two different symbol sequences (A, B), which are transmitted in alternation periodically;

- the chronological position of the signal to be received, and/or the center frequency error between the transmitter (S) and the receiver (E), is ascertained from a composite term of the various symbol sequences (A, B) within a predetermined interval.

2. The method of claim 1, characterized in that in an OFDM transmission system, the symbol sequences (A, B) comprise OFDM symbols, which have the same lengths as or different lengths from a conventional data symbol.

3. The method of claim 1 or 2, characterized in that the symbol sequences (A, B) are transmitted at last in pairs in each case in alternation.

4. The method of claim 1 or 2, characterized in that when there are more than two different symbol sequences, at least one symbol sequence as a pair is put together with a spacing from at least one further pair of another symbol sequence to form the synchronization train.

5. The method of claim 3 or 4, characterized in that guard intervals in front of the individual pairs of symbol sequences (AA, BB, AA, ...) are provided.

6. The method of one of claims 1-5, characterized in that for a block synchronization, the total metrics of the at least two different symbol sequences used as the synchronization train are used, and as the beginning of a block, whichever index minimizes the total metrics within the predetermined interval is selected.

7. The method of one of claims 1-6, characterized in that the predetermined interval is determined by the frame structure of the data stream.

8. The method of one of claims 1-7, characterized in that for estimating the center frequency error, the phase rotation of two adjacent identical signal segments at a time is ascertained.

9. The method of claim 8, characterized in that the phase rotations of other identical signal portions are also ascertained, and the total center frequency error is estimated by averaging via the phase rotations thus obtained.

10. The method of one of claims 1-9, characterized in that the symbol sequences are utilized for channel estimation for a coherent demodulation, in that the symbol sequence

after a frequency correction has been performed is subjected in the receiver to an FFT transformation (Fast Fourier Transformation), and the amplitudes and phase weights of the individual subcarriers are determined.

11. The method of claim 10, characterized in that the channel parameters are estimated by averaging via the various symbol sequences (A, B).

12. The method of one of claims 1-11, characterized in that the synchronization train is preceded by a preamble (P), which is used in particular to adjust the amplitude control (GC) of the receiver (E).

13. A transmitter (S) for preparing a synchronization train for at least one receiver (E) within a transmission system, using a data stream with guard intervals, in particular for compensating for multi-path propagation, having the following characteristics:

- a coding or modulating device (CM),

- an insertion device (EB) for a synchronization train, which is formed of at least two different symbol sequences (A, B), the insertion device (EB) being embodied such that an alternating, periodic insertion of the synchronization train into the data stream prepared by the coding and modulating device (CM) can be performed;

- a memory device (SP), operatively connected to the insertion device (EB), for the various symbol sequences and for their linkage.

14. A receiver (E) for receiving and evaluating a

synchronization train which can be transmitted by a transmitter (S) within a transmission system, using a data stream with guard intervals, in particular to compensate for multi-path propagation, having the following characteristics:

- a sampling memory (AS) for a received data stream;

- a synchronization evaluation device (SY), which is operatively connected to the sampling memory (AS) and is suitable for evaluating a synchronization train, comprising at least two different symbol sequences (A, B) that can be transmitted periodically in alternation, with respect to the chronological position and/or center frequency error within a predetermined interval, and for controlling corresponding reception units for block synchronization (BS), frequency synchronization (FS), and/or channel estimation (KS).

15. A communications system using the method of one of claim 1-12 or an arrangement of claim 13 or 14, which is embodied as a radio communications system, a line-connected communications system, or a hybrid communications system, that is, as a communications system with radio components, optical waveguide components and/or line-connected components, and in which one transmitter and one receiver are assigned to subscribers, with variable transmission and reception modes.

16. A broadcasting communications system using the method of one of claim 1-12 or an arrangement of claim 13 or 14, which is embodied as a radio communications system, a line-connected communications system, or a hybrid communications system, that is, as a communications system with radio components, optical waveguide components and/or line-connected components, and in which the association of

the transmission and reception mode is fixedly specified.

Fig.1

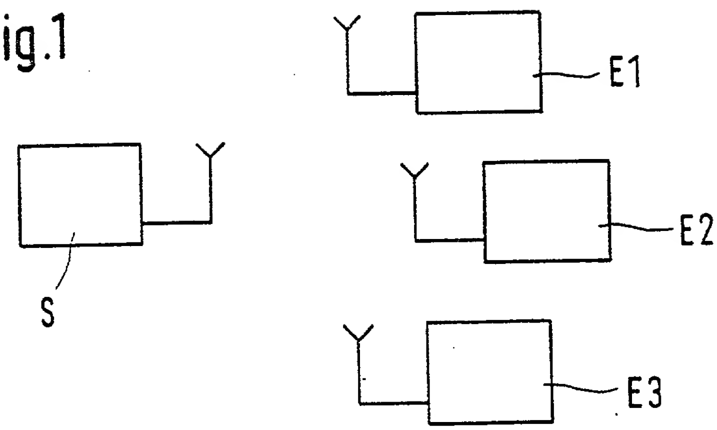


Fig.2

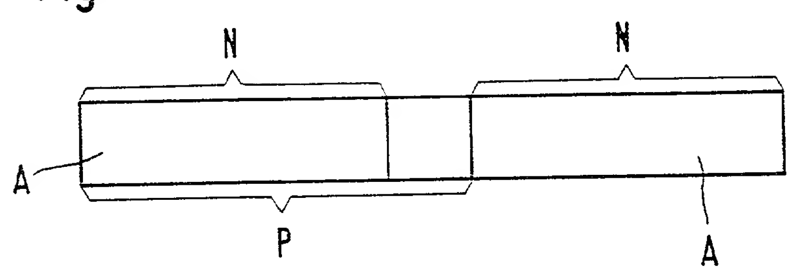


Fig.3

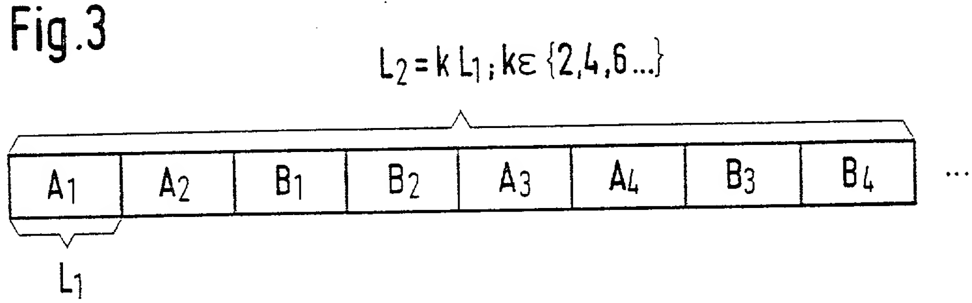


Fig.4

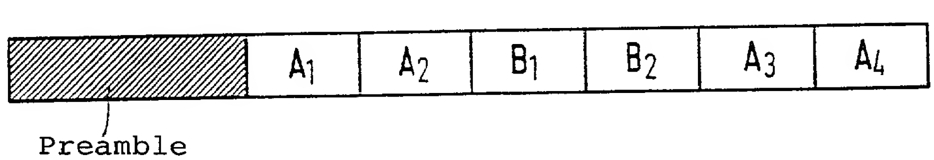


Fig.5

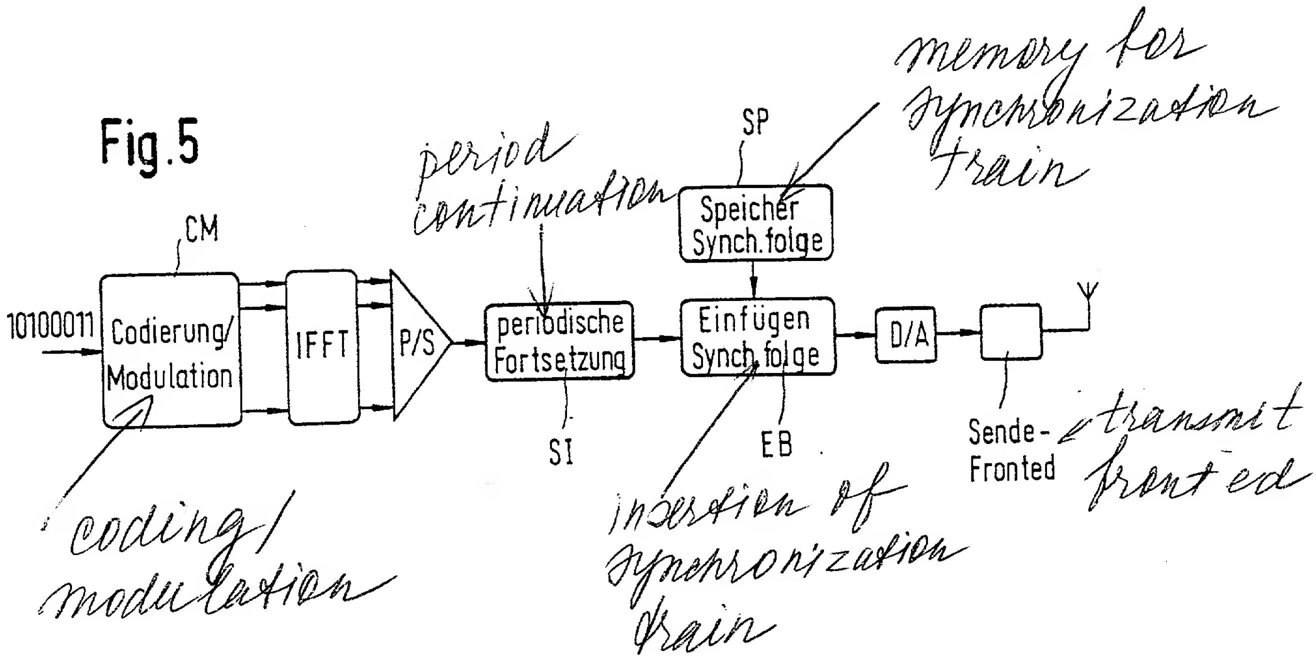
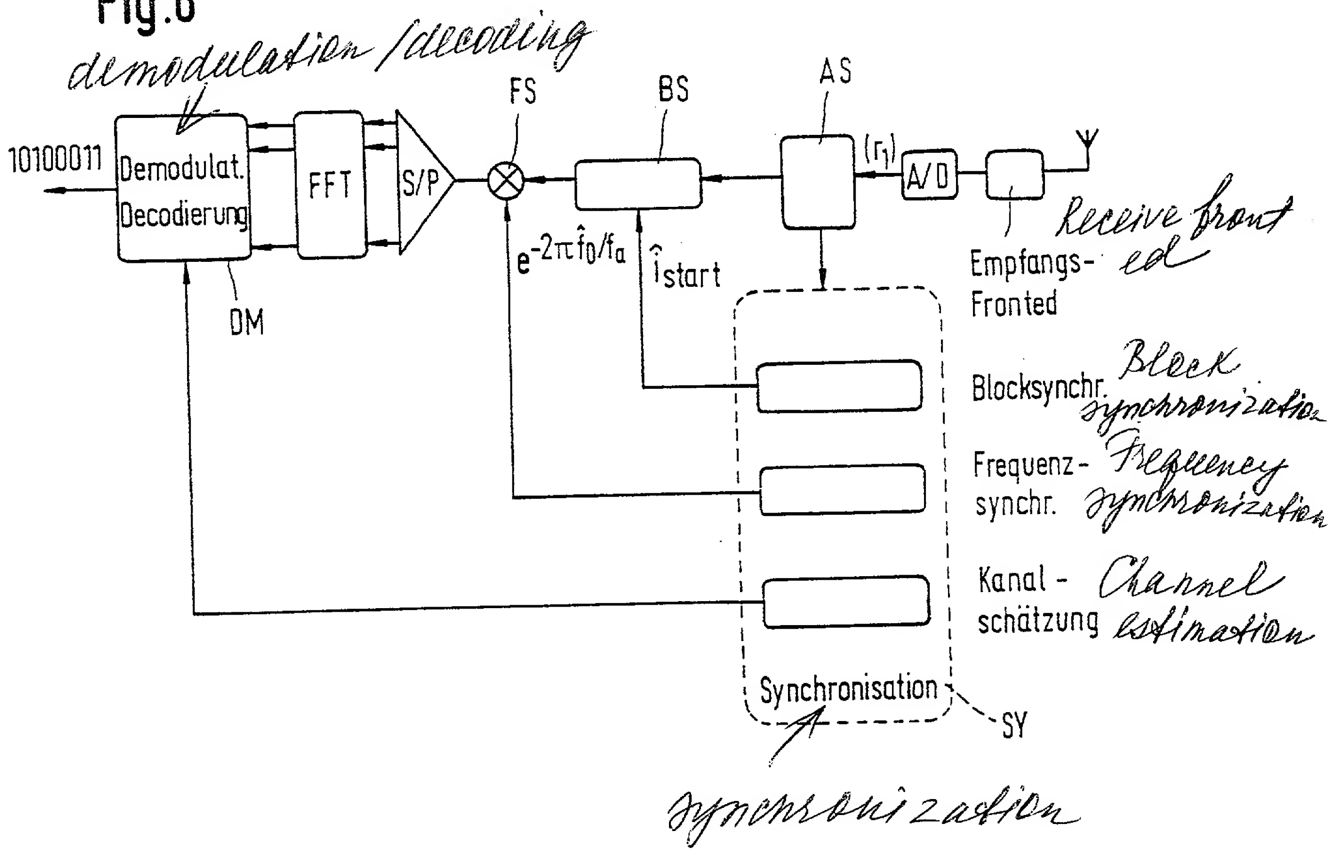

memory for synchronization train
SP
period continuation
CM
Speicher Synch.folge
10100011
Codierung/ Modulation
IFFT
P/S
periodische Fortsetzung
Einfügen Synch.folge
D/A
SI
EB
Sende- Fronted
transmit front ed
coding/ modulation
insertion of synchronization train

Fig.6


demodulation /decoding
FS
BS
AS
10100011
Demodulat. Decodierung
FFT
S/P
(r_1)
A/D
$e^{-2\pi \hat{f}_0/f_a}$
$\hat{l}$start
Receive front ed
Empfangs- Fronted
DM
Blocksynchr.
Block synchronization
Frequenz- synchr.
Frequency synchronization
Kanal - schätzung
Channel estimation
Synchronisation
SY
synchronization

DECLARATION AND POWER OF ATTORNEY FOR NATIONAL STAGE OF PCT PATENT APPLICATION

As a below-named inventor, I hereby declare that:

Markus RADIMIRSCH
Karsten BRUENINGHAUS
Urs LUEBBERT

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD FOR SYNCHRONIZATION** the specification of which was filed as PCT International Application number PCT/DE 00/00915 on March 26, 2000.

I hereby state that I believe the named inventor or inventors in this Declaration to be the original and first inventor or inventors of the subject matter which is claimed and for which a patent is sought.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365 (b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior foreign application(s): Priority claimed:

199 14 600.4	GERMANY	MARCH 30, 1999	X	
(Number)	(Country)	(Date filed)	Yes	No
(Number)	(Country)	(Date filed)	Yes	No

As a named inventor, I hereby appoint the following attorney to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statement

may jeopardize the validity of the application or any patent issued thereon.

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Signature:	Date:	Residence and Full Postal Address:
Full Name of Fifth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Sixth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Seventh Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Eighth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Ninth Inventor:	Citizenship:	